Natural Gas Pathway Analysis for Heavy Duty Vehicles

Matthew Joss
What is the ETI?

- We are a £400m industry and government funded research institute into low carbon energy system planning and technology development to address UK energy and climate change targets
Energy Vectors for HDV

**η**
Hybridisation, lightweight structures, improved aerodynamics and powertrain efficiency could deliver significant reductions in fuel consumption. Costs are a barrier to more aggressive measures.

** Flame**
Small foothold in the HDV market and compliment existing vehicle architectures and efficiency developments.

**Lightning Bolt**
Considering both plug-in hybrids (PHEVs) and pure battery electric vehicles (BEVs).
Barriers are high, but could be more suitable for certain sectors.
Compliment Pass Car.

**H₂**
Continued innovation could enable hydrogen fuelled vehicles to be successful.
Barriers are high.
The Project

• Asses the potential of natural gas as a future HDV fuel

• Build a knowledge base

• Assess fugitive emissions through the pathway (CO₂ and CH₄)

• Create a techno economic and emission analysis model to assess future potential of Natural Gas
Structure

Well-to-Terminal

Base Case

Best Case

Worst Case

Terminal-to-Tank

Tank-to-Motion
Well-to-Terminal

a) LNG

- Best case
- Base case
- Worst case

b) CNG

- Best case
- Base case
- Worst case
Terminal-to-Tank

a) LNG

<table>
<thead>
<tr>
<th>Year</th>
<th>Best case</th>
<th>Base case</th>
<th>Worst case</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>35.4</td>
<td>3.2</td>
<td>0.8</td>
</tr>
<tr>
<td>2020</td>
<td>26.2</td>
<td>4.4</td>
<td>5.1</td>
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<tr>
<td>2025</td>
<td>18.1</td>
<td>3.3</td>
<td>0.7</td>
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<tr>
<td>2030</td>
<td>14.8</td>
<td>0.5</td>
<td>0.3</td>
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<tr>
<td>2035</td>
<td>14.3</td>
<td>0.6</td>
<td>0.3</td>
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b) CNG

<table>
<thead>
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<th>Year</th>
<th>Best case</th>
<th>Base case</th>
<th>Worst case</th>
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<tr>
<td>2015</td>
<td>8.3</td>
<td>3.2</td>
<td>0.5</td>
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<tr>
<td>2020</td>
<td>6.2</td>
<td>1.6</td>
<td>0.5</td>
</tr>
<tr>
<td>2025</td>
<td>3.2</td>
<td>1.7</td>
<td>0.6</td>
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<td>2035</td>
<td>1.2</td>
<td>0.6</td>
<td>0.5</td>
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</table>

Best case, Base case, Worst case
Tank-to-Motion

<table>
<thead>
<tr>
<th>Engine Type</th>
<th>gCO₂eq/km</th>
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<tbody>
<tr>
<td>Baseline Diesel</td>
<td>939.0</td>
</tr>
<tr>
<td>HPDI</td>
<td>720.4</td>
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<tr>
<td>MPSI</td>
<td>780.5</td>
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<tr>
<td>Fumigation Dual Fuel</td>
<td>815.3</td>
</tr>
<tr>
<td>Multi Port Dual Fuel</td>
<td>826.3</td>
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<tr>
<td>Stoichiometric Dedicated Gas</td>
<td>896.3</td>
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</tbody>
</table>

Labels:
- Best
- Base
- Worse

Footnotes:
- Diesel Combustion (and AdBlue Footprint)
- Natural Gas Combustion
- Methane Slip
Tank-to-Motion

HPDI – Substitution rates of 90-95%, direct cylinder injection of the gas

MPSI – Substitution rates of 50-80%, multiple gas injectors located near inlet valves per valve to allow precise timing of injection.

Fumigation Dual Fuel – 30-60% diesel substitution, single point injection system, gas mixes with the air prior to entering the combustion chamber

Multi Port Dual Fuel – 30-60% diesel substitution, multiple injectors but multiple ports per injector

Stoichiometric Dedicated Gas – Diesel replacement spark ignited ignition
The Model

- Well-to-Terminal
- Terminal-to-Tank
- Tank-to-Motion

2015 2020 2025 2030 2035

£
# Uptake Scenario

<table>
<thead>
<tr>
<th>Uptake for Case</th>
<th>Base Case</th>
<th>Best Case</th>
<th>Worst Case</th>
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</thead>
<tbody>
<tr>
<td>Central Scenario</td>
<td>80% (100% for long haul and distribution)</td>
<td>80% (100% for long haul and distribution)</td>
<td>80% (100% for long haul and distribution)</td>
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<tr>
<td>Minimum Uptake</td>
<td>50%</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Maximum Uptake</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Fleet penetration of Gas HDVs (on-road, off-road and busses) in percentage.
**Fleet Emissions**

Total Emissions from Land HDVs in the UK (Million Tonnes CO2eq)

- **Worst Case:** 40.4 MT CO2eq
- **Base Case:** 38.3 MT CO2eq
- **Best Case:** 36.2 MT CO2eq
- **No Natural Gas:** 34.1 MT CO2eq

Year: 2015, 2020, 2025, 2030, 2035

- **↑ 2 - 4%**
- **↓ 4 - 8%**
- **↓ 2 - 5%**
HMRC Fuel Duty – Cost to the Fleet

Total annual spending in £million/year

- **Base Case**
- **No NG**
- **Base Case Central**
- **Duty differential on CO2 fuel content basis**
- **No duty differential**

**Year**
- 2015
- 2020
- 2025
- 2030
- 2035

- **Base Case**
  - £22.8bn/yr
  - ↑ 3.4%

- **No NG**
  - £22.8bn/yr
  - ↑ 7.4%
Overall Conclusions

- Economics for natural gas in the HGV fleet hinges upon the fuel duty differential and currently only the long haul segment is economic in the near term.

- Fuel duty tax stability is key to enable market confidence to invest in natural gas vehicles and the necessary supporting infrastructure.

- Natural Gas has the potential to reduce pathway Greenhouse Gas (GHG) emissions over the Well-to-Motion pathway by:
  - Dedicated - 13% (LNG) – 20% (CNG) per vehicle in the 2035 timeframe.
  - Dual Fuel - 16% (LNG) – 24% (CNG) per vehicle in the 2035 timeframe.
Pathway Technology Conclusions

• Cycle specific powertrain technology selection and pathway optimisation are key to providing GHG emission benefits over given usage cycles.

• Dual fuel and converted engines can have high methane emissions, often being worse than baseline diesel powertrains on a GHG emission basis.

• Providing methane catalysis at real world operating temperatures, i.e. below 350°C.

• Employing ‘best practices’ at LNG, CNG and L-CNG stations is a key driver to providing pathway benefits.
Energy Vectors for HDV

η

flammable

electricity

H₂
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21st and 22nd November

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Questions